# research review

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## ATMOSPHERIC CIRCULATIONS OVER THE NORTH AMERICAN CONTINENT

METEOROLOGY LABORATORY, AFCRL

Ozone concentrations in the stratosphere and upper troposphere have proved to be the best--and, to some extent the only--means for tracing large-scale atmospheric motion at altitudes between 8 and 30 km. Further, certain patterns of ozone concentrations and temperatures may provide clues to the existence of clear air turbulence.

These conclusions were drawn by AFCRL scientists following an extensive two-year program of ozone observations over the North American continent. In a paper presented at a meeting of the American Institute of Aeronautics and Astronautics (AIAA) in San Francisco in July, Wayne Hering of AFCRL discusses the AFCRL program for using ozone as a natural tracer of atmospheric circulations. Since January 1963, AFCRL has measured ozone concentrations at 12 widely separated North American stations. These stations extend from the Canal Zone to Fairbanks, Alaska, and Thule, Greenland. Observations were made by sending instruments aloft by balloon.

AFCRL measurements have presented the first detailed picture of broad-scale distributions of ozone by altitude, latitude and season. Of particular interest are distributions at the tropopause, the boundary between the stratosphere and the troposphere. (The tropopause varies in height from about 18 km in the tropics to about 11 km at mid-latitudes.) This interest grows out of a major goal of the study--namely, that of learning more about the mixing that takes place between stratospheric and tropospheric air.

Because a given volume of ozone cannot be "tagged" and its course followed from one region of the atmosphere to another, how do we go about using it as a tracer of atmospheric circulations? The transport process is derived indirectly. If we know the amount of ozone that should exist at a given altitude regime based on its rate of production and dissipation, then we can assume that observed concentrations in excess (or less than) calculated values result from the transport of air from one region to another.

The AFCRL ozone observations show that mixing of air in the stable stratosphere occurs primarily along well-defined, quasi-horizontal surfaces which have a significant slope downward toward the pole. Thus, ozone is transported northward and downward from equatorial regions. Large average concentrations are found in the polar stratosphere. The maximum concentration at the Thule, Greenland, site is found near the 17-km

level as against 26 km in the tropics.

Greatest mixing of stratospheric and tropospheric air takes place in middle latitudes--an observation supporting previous studies. Injections of polar stratospheric air into the troposphere are a regular feature of the mid-latitude circulation in all seasons. These ozone-rich injections, which occur in association with the development of tropospheric disturbances, are readily identified by ozonesonde measurements. Analysis has shown that stratospheric air injected into the troposphere is rapidly mixed. Ozone concentration is reduced by a factor of 10 in a few days.

High concentrations of ozone in the troposphere may provide a strong clue to the existence of clear air turbulence (CAT). Finding methods for predicting, detecting and avoiding CAT is a major Air Force research goal--and is of obvious interest to the commercial airlines. It has been known for some time that certain temperature structures and wind shear are favorable to the formation of CAT. AFCRL decided to investigate whether or not there might also be a characteristic distribution of ozone associated with turbulence. This would seem likely since the other two factors--wind shears and higher-than-normal temperature--were believed to be caused by the injection of stratospheric air into the troposphere.

A U-2 aircraft equipped with ozone detectors and other meteorological instruments is being used to explore temperature and ozone characteristics in relation to the presence of CAT. Although only a limited number of flights have been made into turbulent areas, results to date are extremely promising. These U-2 flights will continue to establish the mesoscale distribution of ozone, wind and temperature in these areas, and to define the synoptic-scale circulations leading to the formation and decay of the clear-air-turbulence structure. ★


# research review
## OFFICE OF AEROSPACE RESEARCH

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*JACOB SEIDEN*
*Editor*



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# *ULTRASONIC....*

# TEMPERATURE PROBE

**SPACE**
**PHYSICS**
**LABORATORY**
**AFCRL**

Where there's a shock tube, there's usually a temperature-measurement problem. Temperature is measured most precisely when the measurements are direct--that is, when the temperature probe interacts with the hot gas itself. There is presently one good way of doing this (the line-reversal method), but researchers would like to have a second direct method for cross referencing.

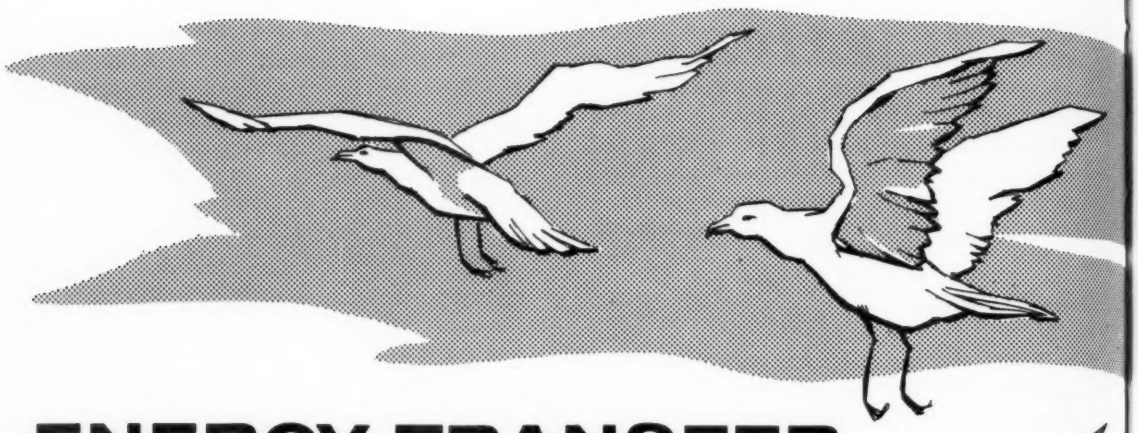
A second method has been developed for use in one of AFCRL's shock tubes. It has been called the ultrasonic temperature probe. The new probe works on the principle that the speed of sound through a gas depends in a well-known way on the temperature of the gas. By sending a one-megacycle pulse through the gas and recording the time it takes the pulse to travel through the gas, the gas temperature can be derived. Many attempts have been made by others to apply this principle to the measurement of shock-tube temperatures, but without notable success. The difficulty has always been that the high noise level of shock-tube operation saturated the detectors. In a recent series of tests, in which measurements were made by both the new ultrasonic probe and the conventional line-reversal method, the temperatures obtained by both agreed very closely.

For experiments being carried out by Dr. Gordon Wares of AFCRL, precise temperature data is an especially critical parameter. The ultrasonic temperature probe was, in fact, developed as an adjunct to these experiments to assure the accuracy of the results. Although the probe was developed specifically for use with the AFCRL 20-foot long shock tube, it has general applicability to a variety of shock tubes.

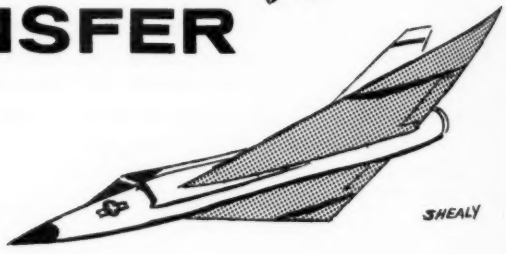
The experiments themselves were undertaken to provide the spectroscopist with a firmer basis for interpreting spectral recordings of the sun, stars and nebulae. Dr. Wares is measuring the ratios of the spectral-line intensities of atoms, ions and molecules to their concentrations. This ratio is proportional to a quantity which spectroscopists call the substance's "f-value." Once the f-values for a number of substances have been determined, astronomers can find the relative concentrations of these substances in the atmospheres of stars and in nebulae by measuring the intensities of their spectral lines. Such studies can help answer questions concerning the relative abundance of various elements in the universe and how the heavier elements were formed from lighter ones during stellar evolution. However, the determination of the f-values needed for these studies is difficult for several reasons; temperature is one of them. Not only are spectral-line intensities different for each element, molecule, or ion; they also vary widely with temperature. Thus, the development of the ultrasonic temperature probe presents a vital step forward in insuring that the f-values obtained in the shock-tube experiments are accurate.

The shock tube used in these experiments employs a ruptured aluminum diaphragm to create a shock wave in the 20-feet long, 2-inch square tube. The tube itself is filled with neon. F-values for each substance are measured separately by mixing a small amount of the substance in gaseous form with the neon in the tube. Helium is placed in a pressure tank associated with the tube. At a given pressure, a diaphragm separating the pressure tank and the tube bursts, creating a shock wave in the tube. The neon is heated to between 3,000 and 8,000 degrees K--the general temperature range at the visible surface of the sun and stars.

The ultrasonic temperature probe was developed under a contract for AFCRL by Dr. E. H. Carnevale of Parametrics, Inc., Waltham, Mass. ★



# ENERGY TRANSFER BY SHEAR FORCES




SIEGFRIED H. HASINGER, Thermo–Mechanics Research Laboratory, ARL

The airfoil is the most prominent example of a mechanical device which efficiently imparts kinetic energy to a fluid medium. Long before the airplane was known, the "airfoil" or "lift" principle was applied intuitively, though crudely, in wind mills and sailing ships. Nature provides the best example in the soaring bird. The modern airplane gave the principle a name, and brought it to such perfection that earlier applications of the lift principle, such as compressors and turbines, have their lift surfaces, i.e., their blades, designed according to airfoil theory.

The airfoil, as a wing of an airplane, transfers energy from the moving airplane to the surrounding air, accelerating it downward toward the earth. The reaction force to this movement is the lift that counteracts gravity. This lift production can be derived from purely potential flow considerations by combining linear and circulatory potential flow systems, i.e., it is of a conservative nature. This implies that the lift mechanism by itself is free of losses. Surface friction or flow separation are only incidental losses to be minimized by a proper technical design. Very strong reasons must exist to abandon this near perfect energy transfer principle in favor of another one.

These reasons exist where the fluid medium involved is a liquid. Liquids are subject to "cavitation" whenever the pressure becomes low enough to cause boiling. This seriously restricts performance, and causes damage and instabilities. Unfortunately, the lift mechanism is a major cause of it. Lift forces manifest themselves as a pressure difference between the two sides of the lift surface, or blade in case of a pump. This causes the pressure on the "suction side" to be, at least locally, below that of the undisturbed fluid approaching the lift surface. Cavitation at these low pressure zones limits the lift action, particularly if the liquid to be

pumped is near boiling, as is frequently the case with liquid gases. In addition, the more refined the lift mechanism is made, the more sensitive it becomes to design deviation, and operational instabilities known as "surge" and "stall" are the consequences. Thus, what makes the lift principle so perfect in efficiency, makes it in many cases intolerable in pumps.

Energy can also be transferred to fluids by means of shear forces produced between layers of fluid or between solid surfaces and fluids moving at different speeds. This energy transfer principle is better known from its negative side as friction. Pumping by friction appears not very attractive. However, the idea of shear force turbo machinery dates back more than 50 years when Nicola Tesla, better known for his electrical inventions, proposed and built a shear force turbine. In recent years, shear force pumps have repeatedly been investigated. However, none of these efforts could rid the shear force pump of the connotation of a friction device. The efficiencies obtained were not much beyond 20% or 30%.

In view of the urgent need for non-cavitating pumps in aerospace applications (rocket fuel pumps, feed pumps in Rankine cycle power plants) and recognizing that energy transfer by shear forces does not necessarily have to be a high loss process, the Thermo-Mechanics Research Laboratory of ARL embarked on a principal clarification of the subject. The basic configuration investigated consisted of two parallel discs, closely spaced, with cutouts in the center. The fluid enters the rotating discs at the center, is then accelerated by the discs and finally discharged at the periphery. The transfer of energy from the rotating discs to the pumped fluid is governed by the momentum laws. In a consistent application of these laws, the principal requirements for dimensioning an efficient shear force pumping device were established, showing that efficiencies twice as high as those so far obtained should be possible.

To refine and particularly to generalize preliminary results, the Applied Mathematics Research Laboratory of ARL was consulted on the basic mathematical representation of the flow between two rotating discs with inflow at the center, a problem of fairly general nature until then unsolved. Their investigation resulted in a classical solution of the Navier-Stokes equations for this flow problem. In particular, it provided the similarity conditions which allowed an elegant optimization of the design of shear force pumps.

An experimental pumping device, consisting of a multitude of discs (about 180) properly spaced (.005 inch) was designed and tested, yielding rotor efficiencies of 62%. As a final investigation in this effort, the cavitation behavior of the test pump was determined. In its preferred domain of application, which lies at lower flow rates and high pump head (at "specific speeds" of around 1000 with flow rate in gpm), the pump operated under near boiling conditions in the inlet with complete stability, and with only slight performance losses. No cavitation damage could be detected in the pump after prolonged testing.

Though the shear force pump still can not compete with conventional pumps on the basis of efficiency, its cavitation behavior is clearly superior, at least for low specific speed applications, as they pertain to feed pumps or rocket fuel pumps. In terms of the "suction specific speed" - the common measure for expressing the cavitation sensitivity of pumps - the test pump, which was designed for maximum efficiency, and not necessarily for high suction specific speed, had at the maximum efficiency point a value (20,000 for flow rate in gpm) twice that of the conventional centrifugal pump. Even higher values were attained at lower flow rates. Shear force pumps designed for high suction specific speeds may, with certain sacrifices in efficiency, obtain values an order of magnitude higher than normally achieved with conventional pumps.

Various agencies have already expressed their interest in the shear force pump and it is hoped that the still existing hesitation to convert a "laboratory device" to an industrial application will be soon overcome. ★

# DEVELOPMENT OF OPTICAL SPACING AND WEIGHING TECHNIQUES IN REGRESSION ANALYSIS

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An application of the statistical theory developed by P. G. Hoel of the University of California, Los Angeles, under the sponsorship of the Air Force Office of Scientific Research, was reported in the OAR Research Review of November 1964. Professor Hoel developed an optimal method for spacing and weighing observations in polynomial regression when one is required to estimate values outside the range of the collected data.

In less than nine months, J. Wolfowitz of Cornell University, also working under the sponsorship of the Air Force Office of Scientific Research, extended the above-mentioned theory to include a large class of nonpolynomial regression problems involving Chebyshev systems. In addition, he characterizes the large class of functions which are optimally estimated by designs supported by these Chebyshev points. A summary of the development of the statistical theory is shown in Figure 1.

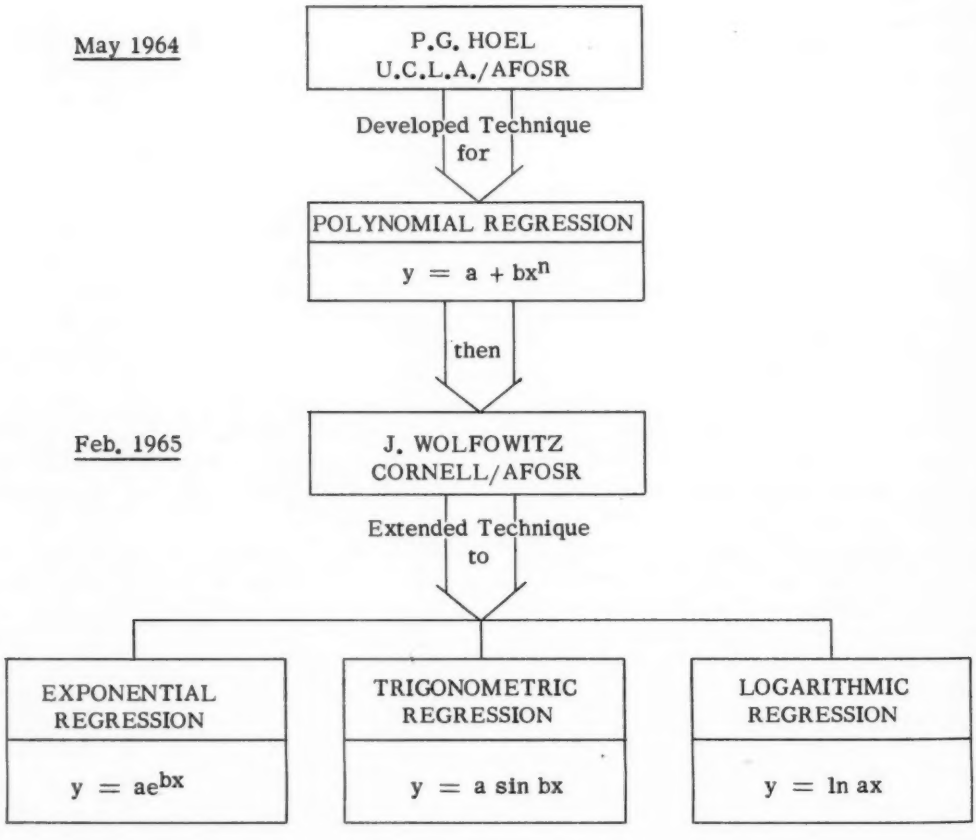


FIG. 1. SKETCH OF DEVELOPMENT OF OPTICAL WEIGHING AND SPACING TECHNIQUES

Although Professor Wolfowitz's main interest lies in other areas of mathematical statistics, he had kept abreast of regression analysis by maintaining his acquaintance with Professor Hoel. He reports that his effort to extend the theory was motivated by receiving an advance copy of Professor Hoel's research paper.

The work of both men is of interest to applied and theoretical statisticians. Professor Hoel's work applies to polynomial regression problems. Professor Wolfowitz's results are applicable to regression problems when the relationship between the independent and dependent variable is a transcendental function. Important and frequently used transcendental functions are the exponential, logarithmic, and the trigonometric. ★

# ROCKETS AND SATELLITES FOR RESEARCH - THE AEROSPACE RESEARCH SUPPORT PROGRAM

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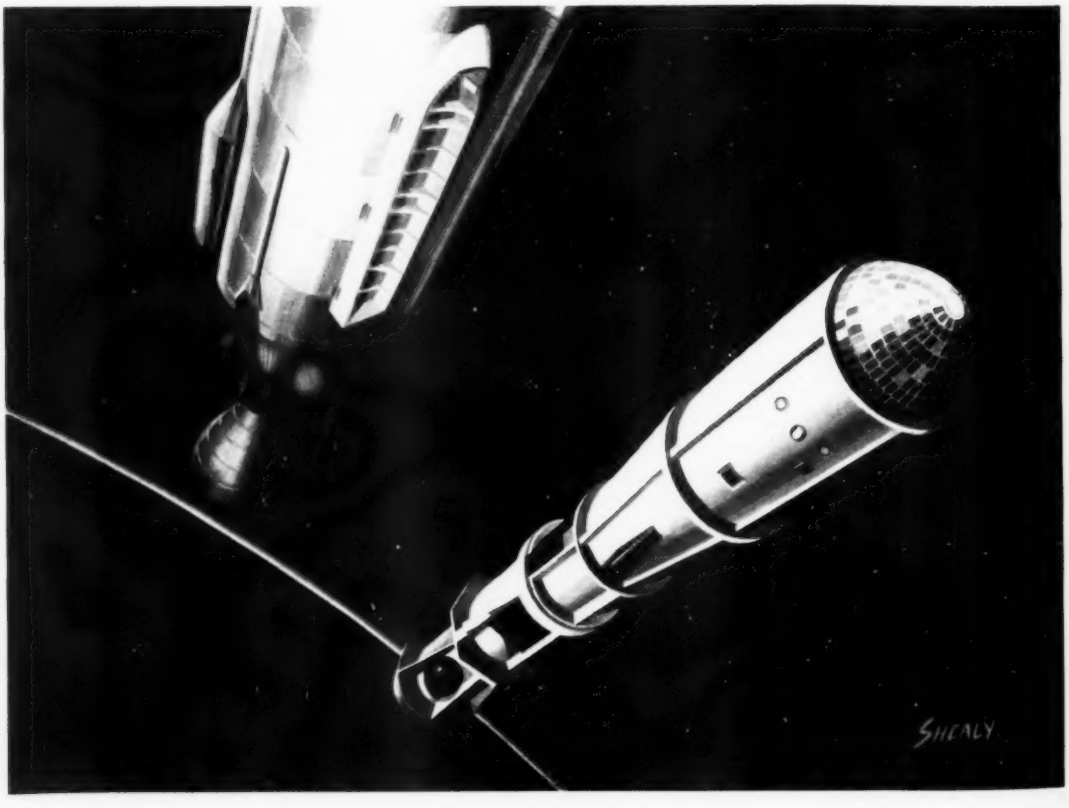
The Aerospace Research Support Program (ARSP) is frequently the gateway to space for Air Force scientists and engineers. A joint Air Force Systems Command/Office of Aerospace Research program managed by OAR, the ARSP is designed to provide the laboratory scientist/engineer the necessary hardware and services to get his experiment into the space environment. The experiment may be concerned with investigation of the space environment itself or with the reaction of some equipment, technique, or material combination to the environment. Examples of experiments in the two categories are cosmic-radiation measurements in the first case, and determination of space-environmental effects on cadmium-sulfide solar cells in the second. Regardless of which of the categories his experiment fits, the experimenter is eligible for ARSP support if he operates in the Air Force's research or exploratory development areas of endeavor. Depending on the time, altitude, and space-volume coverage he needs, his experiment may be afforded anything from a few minutes of ballistic trajectory from a small sounding rocket at the upper fringes of the atmosphere to a boost by a Titan III space giant into a synchronous orbit of the earth.

The ARSP is now in its fifth year of operation. In this time, the program title has evolved from "Probes Program" through "Aerospace Environmental Research Program" to its present form. It is also known by its Air Force project number - 7043. The program's scope has broadened from the purchase of a few small sounding rockets to include the design and development of specialized spacecraft which can take advantage of the excess pay-load-carrying capacity which many Air Force boosters have.

The ARSP came into being when it was recognized that the individual Air Force scientists and engineers who had requirements for experimentation in space were either unable to obtain the time and money to buy and fly their own rockets or, if they were attempting to proceed unassisted, were functioning in a most inefficient manner. To bring order to the process, to take advantage of "quantity-buy" prices, to combine numbers of experiments into optimal pay loads, and to provide several necessary services common to all potential experimenters, the "probes" program was initiated in 1960. It continues to exist and to grow for only one primary purpose--the return of scientific or engineering data from the experiments it supports.

At first, the "probes" program was envisioned as the supplier of small sounding rocket vehicles and an occasional deep-space probe or even an orbital Scout. Operation along these lines was attempted during the first years. It soon became evident, however, that the experimenters wanted longer or higher or differently oriented exposures to space environment than most of the small vehicles could provide. At the same time, the Scout vehicles which had been depended upon to furnish "cheap" orbital flights were becoming more expensive and their present-day reliability had not yet been fully realized. Some of the alternative means of providing the requested rides have been "piggyback" or secondary pay-load rides on various Air Force satellite programs, attachment of ballistic "scientific passenger pods" to Atlas and Titan ICBM's, and finally, development of an "orbital pod" and several complete piggyback satellite pay loads. The "orbital pod", known as the OV1, is a unique development concept. It was designed to ride "piggyback" on an Atlas ICBM until the Atlas sustainer engine cutoff, then separate itself from the parent missile and, with its own guidance and propulsion, inject its scientific pay load into a prechosen orbit. Now that some of the early Atlases are no longer needed in the operational missile inventory, it has become possible to use their boost to fly two of the OV1's from a single launching - a very economical prospect.

As the national space programs have matured, the requirements of Air Force experimenters have increased with regard to both the numbers and sophistication of orbital flights. A couple of years ago, no one in our laboratories apparently even dreamed of anything so sophisticated as secondary pay-load rides into synchronous orbit. But, since the vehicles to provide such orbits are being developed (Titan IIIC) and have secondary-pay-load capacity avail-



able, the requirements for such orbits by AFSC and OAR laboratory experimenters have appeared. Similarly, experimenters who were once content with sounding rocket flights are now submitting orbital flight requirements.

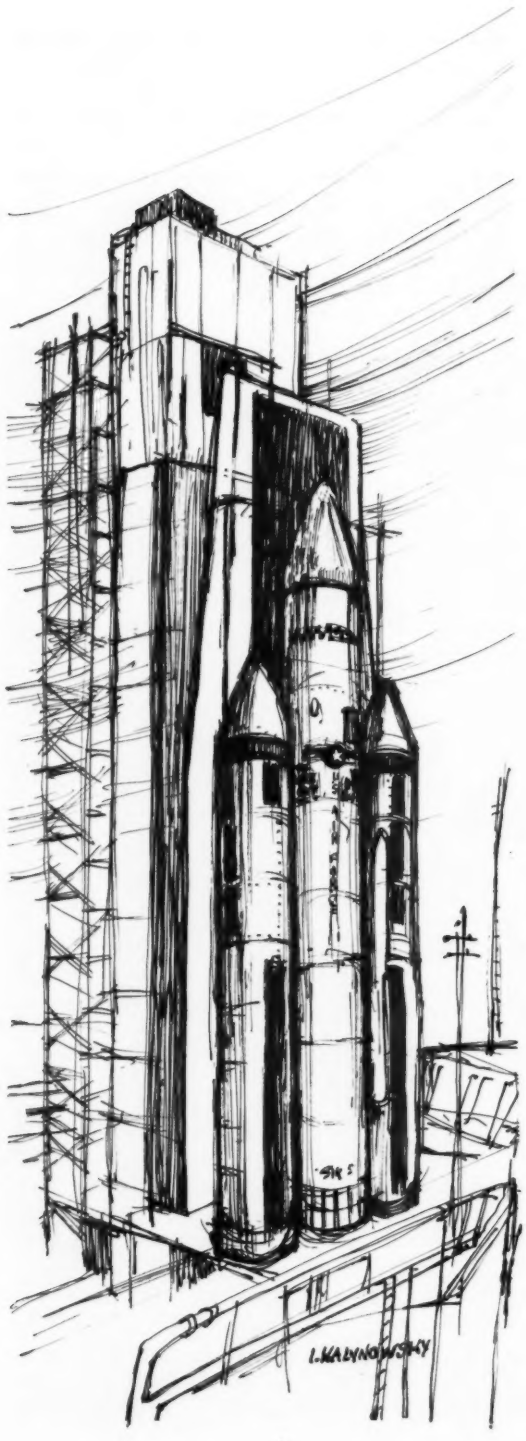
There are three elements of the ARSP way of obtaining experimental data from space. These are program formulation, hardware implementation, and operation. Program formulation is the process of selecting the experiments to be supported. Even if all the resources were readily available--which they are not--to support every proposed space experiment, some screening process would be necessary to maintain a clear conscience regarding the worth of the program. With limited resources, it is absolutely necessary to insure that only the "best" experiments use those resources.

A number of checks and reviews are used to provide the necessary insurance. The first of the checks is the assurance given by the experimenter's laboratory that the experiment is a valid part of the laboratory's program, and that the fabrication and testing of the experimental hardware and subsequent reduction and use of the data may be expected through expenditure of laboratory resources. The next check point is the review of each experiment by a Pay-Load Review Meeting of the experimenters themselves--the "peers" of the individual experimenter. This so-called Phase I meeting produces a priority list from the scientific/engineering viewpoint. Factors which are considered in the review are scientific/engineering merit, scientific method, and feasibility. A second review, called Phase II, puts any managerial modifications necessary on the priority list and establishes monetary cutoff points suitable to various possible funding levels for the ARSP. Further checks by higher headquarters (Air Force and DOD) and with NASA (for undesirable duplication of NASA space sciences activities) are made before the year's program becomes final.

Planning for the implementation phase is a continuous process. The lead times for obtaining prime space boosters, secondary rides on boosters or spacecraft of other programs, and fabrication, testing, and integration of pay-load packages or spacecraft are such that a year-round activity is necessary to any semblance of efficiency. At any given time, then, the "buy" program may have booster vehicles, spacecraft, or other capabilities (such as space-available on a prime booster) in "inventory" for which the pay-load experiments have not been identified. Or there may be a backlog of experiments for which the launch vehicles or spacecraft have not yet been obtained. Occasionally an experiment is withdrawn by the experimenter for scientific or financial reasons. The ARSP then adjusts to the withdrawal by attempting to find another pay load for any vehicles which have been obtained or planned.

Implementation of the planned program is accomplished through contracts for vehicles and associated hardware and through services performed by ARSP people and the experimenters themselves. An ARSP office which is concerned almost entirely with this implementation is located with the Space Systems Division of AFSC in the Los Angeles complex. Here the specific duties are those associated with obtaining spacecraft, obtaining boosters or secondary rides, and the integration of experiments to spacecraft and spacecraft to boosters. In some cases, the vehicle contracts involve procurement of boosters and in other cases not. The ARSP services include preparation for the desired range support, providing facilities for storage and handling of the flight vehicles and arranging for delivery of the experimentally obtained data (which is the program payoff) to the experimenter.

The space-launch operations of the ARSP take place at a number of locations associated with the various national and/or Air Force rocket-launching ranges. These include the Eastern Test Range at Patrick AFB, Florida; Western Test Range at Vandenberg AFB, California; White Sands Missile Range in New Mexico; Eglin Gulf Test Range in Florida; NASA Wallops Island Test Site in Virginia; and the Churchill Research Range in Canada. Actual launching, tracking, and



data taking is performed by the range organizations. However, the complexities of launch preparation for, and data collection from, orbital and deep-space probe vehicles are such that it is necessary to maintain ARSP field offices at the Eastern and Western Test Ranges.

These field offices serve as hosts to the individual experimenters during pre- and postlaunch activities, providing guidance and assistance in the preparation of range documentation, positioning of checkout equipment and "clean-room" checkout facilities on the one hand, and facilities for "quick-look" checks of the received data on the other. Perhaps the most important aspect of the field offices' activities is their ready availability to the launch and range operations organizations as a single point of contact for all matters pertaining to ARSP pay loads. Additionally, in those cases in which two or more laboratories have experiments aboard the same spacecraft, the field offices must assume the responsibility for any decisions involving the whole vehicles (go/no-go, etc.).

As have the more operational varieties of missile and space programs, the ARSP has had its "holds," "aborts," and "slippages"--all of which can be classified as growing pains or learning experiences. The many small details, which govern the success of space flights more than do grand concepts, have been brought under systematic control. The program thus has matured and is today a more useful service to Air Force scientists/engineers than was originally conceived. This year (1965) the program will support the launchings of about 139 small sounding rockets of all sizes, 6 deep-space probes and 5 satellites. In 1966, the number of ARSP satellites scheduled for launch is 11. Although it is not anticipated that such a large number of satellites will be launched for ARSP participants in subsequent years, most requests by Air Force experimenters to the ARSP can probably be honored. ★

*(Note: Potential ARSP experimenters may find detailed information on the program in the Aerospace Research Support Program Handbook, a blue-covered looseleaf notebook available in each Air Force research and exploratory-development organization.)*

# EFFECTIVE TECHNICAL WRITING.....

COL. JAMES A. FAVA
Office of Scientific and Technical Information
Hq OAR

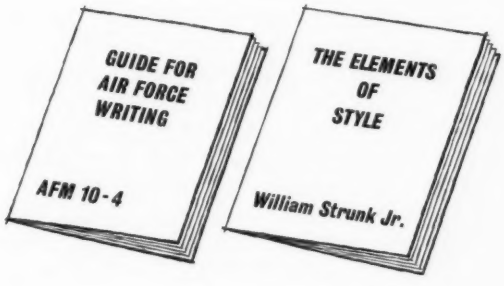
## It can be done!

Throughout the world, an estimated one to two million scientific articles are published annually. Of these, about one half to three quarters are in English. In this roundabout way it is easy to establish the importance of the English language. But who can provide even a ballpark estimate on the number of scientific articles and reports occupying dusty shelves because the authors failed to effectively communicate their findings? More important, can anyone even speculate about the results of research that did not get to the potential users because of uncommunicative titles or uninformative abstracts? Or the corollary delay in the application of research findings that cannot be easily retrieved? Observations such as these cannot help but highlight the absolute necessity for improving our technical written communications.

Yet, this is easier said than done. Unfortunately, differences of opinion, misconceptions, and lack of understanding exist on what constitutes effective writing in the technical sense. Additionally, many authors simply do not know what is expected of them. This situation is aggravated by the fact that supporting agencies can only provide general policy-type parameters; personnel on the working level seek specific guidance.

In order to find some common ground on the necessary prerequisites for scientific writing, let us consider three areas: (1) the interface between common good-writing practices and technical reporting; (2) the guidance available from sponsoring agencies; and (3) the specific aids available to the individual scientific author.

Now for the inferred fundamental differences between good writing in a general sense and technical efforts. My conclusions are based on conversations with colleagues, publishers and established editors; they are based on daily contact with a wide range of scientific and technical reports and publications. In short, I am convinced that the essential elements of effective written communication are the same whether you are writing a personal essay or a scientific report--only the content differs. The salesmanship is the same, i.e., the special effort to create interest that effective writers in all fields use--the efforts that these writers make to transmit a desire to the reader to want to read the document regardless of the specific content. The use of plain English words is one such effort. For example, one of the points brought out at the Seminar of Communicating with Technical Men, held by the editors of International Science and Technology magazine on 9 June 1965, was that articles headlined in nontechnical terminology were more likely to be read. This is nothing more than following the principles of good writing already proven successful in the literary field. If you accept this premise, there are a number of aids already on the market that can assist writers--essayists and technical reporters alike. (1) (2)




Now let us take a look at the guidance available from supporting agencies, particularly as it affects OAR authors.

Early in 1963, the President's Science Advisory Committee published a report (3)

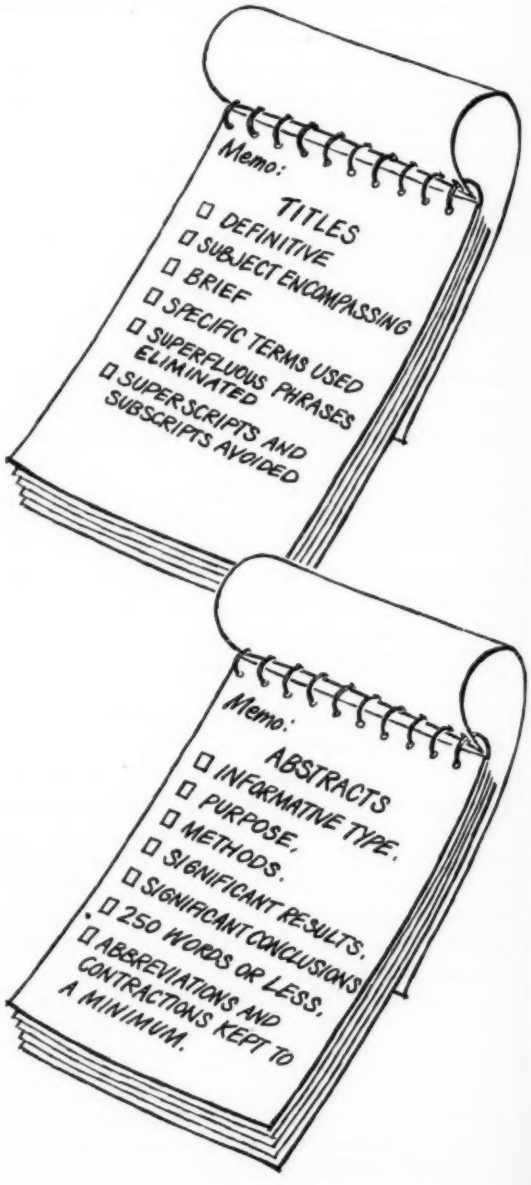
which became known as the "Weinberg Report" after Dr. Weinberg, Chairman of the Panel on Science Information, Oak Ridge National Laboratory. The report dealt with responsibilities of the technical community and the government in the transfer of information. It proclaimed that the transfer of information is an inseparable part of research and development and pointed out that the later steps in the information-transfer process, such as retrieval, are strongly affected by the attitudes and practices of the originators of scientific information. Consequently, the report urged the authors of technical papers to title their papers in a meaty and informative manner, index their contributions with key words, and to write informative abstracts.

A year later the Department of Defense (DoD) issued a directive (4) (implemented by Air Force Regulation 80-29), which requires the authors of reports derived from Defense R&D activities to prepare a special bibliographic form (DD Form 1473) as a part of each report. Among other requirements, this form is to contain informative abstracts and appropriate index terms.

Also, the Air Force recently came out with a directive (5) to describe on a DD Form 1498 research and exploratory-development-type efforts currently in progress. Normally, this is to be accomplished by the scientist or engineer responsible for the work. This, actually, is the first opportunity for the individual author in the Air Force to effectively communicate his ideas, his intentions, his methods and the direction he is going.

In the Weinberg Report, and in the DoD and Air Force directives, then, we find our general guidelines. They do not, however, establish any criteria of "meaty titles" or "informative abstracts." This brings us to the third point--specific aids for individual authors. Because of the general absence of such definite criteria, the Office of Aerospace Research prepared an Author's Guide for Technical Reporting (6). This publication is aimed at both OAR in-house scientists and OAR contractors and grantees, and provides the necessary specifics for more effective writing.

This guide has proven to be a well-thumbed reference. It pinpoints in detail what is expected of the technical reporter. More important, it is chock-full of specific examples. Covered in depth are such subjects as OAR publication policies, criteria for good titles, report introduction, standards for abstracts, selection of key words, and writing style. Three of the many check lists in this publication are illustrated.



Memo: KEY WORDS
☐ WORDS OF SPECIAL SIGNIFICANCE FROM THE TITLE AND ABSTRACT
☐ NEW WORDS NOT FOUND IN THE TITLE OR ABSTRACT DEALING WITH:
☐ MATERIAL/EQUIPMENT/SYSTEM WORKED WITH
☐ PROCESSES/TECHNIQUES/OPERATIONS PERFORMED
☐ PROPERTIES/CHARACTERISTICS/ATTRIBUTES DEMONSTRATED
☐ GENERICS
☐ WORDS WHICH SHOW RELATIONSHIP OF THIS WORK TO OTHER DISCIPLINES OR APPLICATIONS.
☐ ENTERED ON THE DD FORM 1473

To sum up, the job of a scientific investigator is not completed when the results of research are entered in laboratory diaries: for results to get to the potential user they must be effectively communicated. This requires a certain salesmanship--the reader must want to read the document. Good references with concrete examples for individual authors are available. Let's use them. ★

*REFERENCES*


(1) *Air Force Manual 10-4. "Guide for Air Force Writing," 1 April 1960.*

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# Steric Hindrance - A Friendly Conversion


DR. GLEN R. BUELL
Chemistry Research Laboratory, ARL


The inhibiting effect of the size and shape of groups in a compound on the rates of reaction of the compound is commonly referred to as steric hindrance. These effects have long been a major concern of the synthetic and theoretical chemist. The guise taken by steric hindrance ranges from a friendly antagonist who keeps the researcher on his toes to an unyielding opponent who defies all attempts to circumvent his powers. However, only in rare cases is steric hindrance an ally in research.

Dr. Leonard Spialter, Dr. Glen R. Buell and Mr. Charles W. Harris of the Chemistry Research Laboratory, Aerospace Research Laboratories (1), have recently investigated such a case during their studies on the nickel-catalyzed hydrogenation of the tetraphenyl derivatives of silicon, germanium, tin and lead. They have found that the sterically crowded tetraphenylsilane absorbs hydrogen readily, yielding tetracyclohexylsilane. The greater size of germanium, tin and lead reduces the crowding about the central atom, making the phenyl groups more "open" to chemical attack. However, the more "open" and, therefore, presumably more reactive tetraphenyl derivatives of germanium, tin and lead failed to take up hydrogen. In fact, it was determined that the presence of one of these unreactive species severely retarded the reaction of hydrogen with tetraphenylsilane, implying a poisoning effect of these "open" compounds through coordination of the central metal atom with the nickel catalyst.

Since silicon is so closely related to the other Group IVb atoms, it might logically be expected to display the same poisoning behavior. Indeed, it was found that the less-hindered triphenylsilane does poison the hydrogenation catalyst. It is then apparent

that the hydrogenation of the phenyl groups in tetraphenylsilane and related compounds is practical only after the more favorable poisoning action between the silicon atom and the catalyst has been sterically "handcuffed."

Continued research into the effects of steric hindrance is expected to add insight into the fabrication of materials of controlled and selected reactivity. ★

*REFERENCE:*

*(1) Spialter, L., G. R. Buell and C. W. Harris, "Poisoning Effects and Steric Facilitation in Catalytic Hydrogenation of Perphenylated Group IVb Atoms," Journal of Organic Chemistry, 30, 375, 1965.*

# *LASER PHOTOGRAPHY & ATMOSPHERIC PARTICLES*

## METEOROLOGY LABORATORY, AFCRL

Laser or lensless photography--in which the photographic record is not an image but a recording of diffracted light waves known as holograms--is currently undergoing widespread popularization. Potential applications are many; existing ones are few.

An outstanding exception is an instrument developed by Bernard A. Silverman of AFCRL and Technical Operations Research people (Burlington, Mass.) for measuring the size distribution of particles suspended in the atmosphere--raindrops, aerosols, ice crystals, snowflakes and cloud and fog droplets. The unique instrument, known as the laser disdrometer, gives the researcher his first clear view of the distribution of these particles in situ, undisturbed by the measuring or detecting processes.

To understand the performance of this instrument, let's look first at the holograph principle, and then at the kind of information it produces. The recorded image itself (the negative) is simply a photographic record of the diffracted light waves produced by interaction of coherent laser radiation with the particles. The image of the particles can be reconstructed by using another monochromatic light source (usually a laser) to illuminate the recorded hologram.

With this technique, it is possible to collapse all images located in a three-dimensional space onto a two-dimensional photographic record. In reconstructing the volume, it is possible to "move" through the volume of space and observe sizes and distributions of droplets along successive planes within the volume. The effect is curious and fascinating. In quite a literal sense, a "motion picture" can be reconstructed from a single photographic frame. Still more curious is the fact that, as we replay our record and "move" through the volume, the droplets in the foreground become defocused, while droplets further away (including droplets behind others in the foreground) come into focus. The two-dimensional diffraction pattern record can be used to reconstruct the size, shape and relative position of each particle within the original volume.

The disdrometer can assume many configurations. AFCRL and Technical Operations Research personnel are investigating the merits of several of these for a number of applications. One is for an airborne system, to be flown in clouds, capable of recording water droplets, ice crystals, hailstones and snowflakes simultaneously. For this airborne system, laser pulses of extremely short duration (on the order of 20 nanoseconds) will be used to counter aircraft speeds. Both ruby and gas lasers have been used in experimental systems for hologram recording. A cw light source is used to reconstruct the image. Common to all disdrometer configurations is a laser light source at one end of the system and a recording film at the other, with the volume to be sampled between the two. One model used by AFCRL has a length of about six feet.

The laser disdrometer was originally developed as part of AFCRL's study of the formation, evolution and dissipation of fog. This study has the ultimate goal of developing techniques for forecasting fog and for artificially modifying it. AFCRL has had the fog study under way for the past two years at Otis AFB, Mass. The disdrometer has already proved itself to be an incomparable instrument in these studies. ★

# COMPREHENSIVE SURVEY OF PLAYAS PUBLISHED

## TERRESTRIAL SCIENCES LABORATORY AFCRL

The vast, smooth plain of Utah's Bonneville Salt Flats, where for decades experimental vehicles have broken speed records, is a playa. The flat desert near Edwards AFB, California, providing a natural runway of many miles, where the X-15 and other Air Force experimental aircraft have been tested, is also a playa. These are two of the some 60 odd playas in the western United States which have been studied by AFCRL and its contractors during the past several years.

The results of these studies are published in a comprehensive report recently issued by AFCRL. The report is one of the most complete studies of playas yet compiled. This publication, Geology, Mineralogy, and Hydrology of U.S. Playas (AFCRL-65-266), is edited by Captain James T. Neal, who also prepared the introductory chapter. The report covers the origins, general surface characteristics, hydrologic aspects, physical properties, and mineralogy of major U.S. playas.

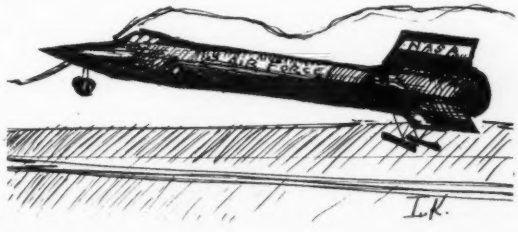
A playa, to a geologist, is a dry lake bed. Colloquially, playas are known as clay pan, salt pan, salt marsh, and so on. Playas are the flattest of all land forms, often sloping only one foot per mile or less. In the desert areas of North America there are several hundred playas over three square miles in area. They are found all over the world, usually in arid or desert areas.

They are, of course, of interest to the Air Force--as natural landing fields for military aircraft, for space-vehicle recovery areas, and for the placement of large antenna arrays. These potential Air Force uses gave rise to the AFCRL study.

In the report, Neal discusses the common features of playas, and their differences. One common feature is that in the history of each there was--and is--the action of ground water. All playas are topographically enclosed basins, with interior drainage, and all exist in an area where evaporation exceeds precipitation. There are a diversity of types, and these types came about through several evolutionary channels. Local temperature, rainfall, mineralogy and geology all play parts in determining whether the playa surface will be hard, dry and compact, or soft, moist and porous, whether the surface will be smooth or flaky, whether mounds and fissures will develop, and whether the surface will be salt-encrusted or carbonate. Some playas provide excellent natural landing areas throughout the year, while others at certain times become covered with shallow sheets of water.

We tend to think of these desert areas as timeless and unchanging. The geologist regards them as dynamic land forms. They are continually changing in response to rain, evaporation, sedimentation, and water table fluctuation. In general, the soil is impervious, which means that following a heavy rain a playa can become completely flooded. In the dryer climates, evaporation can take place at the rate of three inches of water a week. Evaporation rates are decreased, however, depending on the salinity of the water. (Evaporation of the Dead Sea, or the Great Salt Lake, for example, is relatively low.) The long-term effects of winds--erosion, silt transport, and so on--are relatively slight.

The 175-page report emphasizes those characteristics of playas having a bearing on potential Air Force uses. It is well-illustrated and referenced, and is sufficiently broad in scope to serve well as a textbook on this special aspect of geology. ★



# PROFILES

*Dr. Glen R. Buell of the Chemistry Research Laboratory, ARL, is the author of "Steric Hindrance–A Friendly Conversion" which appears in this issue of the OAR Research Review. Dr. Buell is doing research in the field of organo-silicon chemistry with emphasis on steric and electronic factors which influence the hydrogenation of phenylated group IV elements. He received his Ph.D. in Chemistry from the University of Kansas in 1961 and was a research chemist with the Pittsburgh Plate Glass Co. until coming to ARL in 1962.*

*Mr. Attwell M. Adair is a metallurgist and a project scientist with the Metallurgy and Ceramics Research Laboratory, ARL. He is coauthor in this issue of the OAR Research Review of "The Fatigue Limit Behavior of Zone Refined Iron," which describes current research intended to show if the attainment of carbon and nitrogen in metal is of itself sufficient cause for a change in fatigue limit characteristics. Mr. Adair received his MS in Metallurgy from Ohio State University in 1954, and has been with ARL as a military and a civilian scientist since that time. Other current research efforts include an investigation of the effect of interstitial hydrogen on the yield and fracture stress of zone refined iron and a study of low-temperature yield points in metals.*

*Mr. Siegfried Hasinger writes on "Energy Transfer by Shear Forces" in this issue of the OAR Research Review. Mr. Hasinger is a research scientist with the Thermomechanics Research Laboratory, ARL, and is currently engaged in studies of particle dynamics as applied to production of hypervelocity particles and direct electrical energy conversion methods. He is also investigating momentum transfer by shear forces as a possible means of overcoming cavitation difficulties in the pumping of near-boiling liquids. Mr. Hasinger is a 1937 Dipl. Ing. graduate of the Technical University of Munich, Germany, with a major in Technical Physics.*

*1st Lt Frank E. Rizzo, an ARL research metallurgist with the Metallurgy and Ceramics Research Laboratory, has been with the Aerospace Research Laboratories since September 1964. Prior to that, he was an instructor in Metallurgical Engineering at the University of Cincinnati. Lt Rizzo has a B. Ch. E. from the University of Detroit (1961), and an M.S. (1963) and Ph.D. (1964), both from the University of Cincinnati. He is associated with the American Society for Metals, and the Metallurgical Society of AIME. In this issue of the Review, Lt Rizzo writes on "Diffusion Analysis by X-ray Emission."*

*Mr. James A. Wimmer joined the Aerospace Research Laboratories as a physicist in February 1964. He is a member of the Ceramics Research Group, Metallurgy and Ceramics Research Laboratory. His work is primarily in the area of defect structure and electrical properties of high-temperature ceramic materials. Mr. Wimmer has a B.S.E.E. (1962), and an M.S. in Materials Science (1963), both from Marquette University. He is a member of Eta Kappa Nu, Electrical Engineering Honorary; Sigma Xi, Graduate Honorary; I.E.E.E.; and the American Ceramic Society. He was coauthor of the article, "Composition Equilibration in Refractory Oxides," which appeared in the July 1965 Review.*

*Dr. Harry A. Lipsitt is a supervisor of metallurgical research in the Metallurgy and Ceramics Research Laboratory, ARL. He is coauthor of "The Fatigue Limit Behavior of Zone Refined Iron" which appears in this issue of the OAR Research Review. Dr. Lipsitt has been with ARL since 1956 when he received his Ph.D. from the Carnegie Institute of Technology. He is currently involved in research which includes a study of the mechanisms of fatigue limits in metals where efforts are centered around close-packed hexagonal metal titanium (and alloys of Ti) with interstitial elements. He is also taking part in examinations of: the fatigue limit in pure iron; the anamalous elastic behavior of chromium near the Neel temperature; and the metallography of crack propagation in cumulative damage fatigue tests.*

# Laboratory Investigations of the Earth's Mantle

MAJ. DURWARD D. YOUNG, JR.
Directorate of Physical Sciences, AFOSR

The interior of the earth is composed of 3 principal layers: the crust, varying from 5 to approximately 50 kilometers; the mantle below the crust, extending to depths of approximately 2,900 kilometers; and, below this, the central core. While man is far from obtaining more than a superficial understanding of the nature of the crust, he must also look into the mantle for a more complete understanding of the earth's structure. This is necessary since it is probably in the mantle that the forces originate which control conditions of the crust and, indirectly, man's destiny. Here is found the source of volcanoes and mountains, faults and their resultant earthquakes, and much of man's present and future mineral wealth.

Since no samples of the earth's mantle are available for analysis,* samples of the probable constituents must be fabricated. This is therefore a laboratory-research effort which has two basic objectives: (1) to find which fabricated mineral compounds are most suitable for laboratory high-pressure tests of properties of the earth's interior, and to use these to obtain (2) a more satisfactory and therefore useful description of the velocity-density relationship in the earth's mantle. Once such laboratory-analysis techniques are established, it may finally be possible to apply exact methods to the almost abstruse science of geology and thereby permit precise interpretation of geophysical data.

The elements most abundant in the earth's crust and mantle are known. Compounds (minerals) composed of these elements are probably representative of the constituents of the mantle. Nine of these minerals are oxides,* and account for 98% of all the material in the crust. It can be surmised that this will also hold true at least for the upper part of the mantle. Besides their great abundance, oxides are also interesting because their longitudinal and shear velocity increases with density instead of decreasing as one would expect from the classical velocity equations for compressional and shear waves.

$$V_\rho = \sqrt{\frac{K + \frac{4\mu}{3}}{\rho}}$$

$$V_s = \sqrt{\frac{\mu}{\rho}}$$

where
$\rho$ = density
$\mu$ = rigidity
k = bulk modulus

Data on elastic constants of minerals were systematized from numerous sources into groups and plotted on log-log graph paper displaying bulk modulus versus specific volume (per ion pair) for members of each group. Figure 1 shows such a plot where the lower dotted line represents the alkali halides and the upper dotted line the covalent solids.

The interesting feature here is that all groups except the oxides have nearly a -1 slope. They appear to act in a manner expected from classic ionic crystal physics in that there is no discernable effect due to crystal class and the compounds are sorted according to valence. The oxide compounds are different in that the slope of the curve is larger and the points lie nearly on a single line irrespective of valence. The conclusion to be drawn from this presently limited data is that it appears that a change of volume has the same effect on the bulk modulus of oxide compounds whether the volume change is produced by temperature, pressure, or compositional variation. Therefore, it appears that equations of state which have been derived by experiments on alkali metals or alkali halides may not be safely applied to interpretation of data to study the earth's mantle.

*Project MOHO has not yet cored through the crust into the mantle.*

*$SiO_2$, $Al_2O_3$, $Fe_2O_3$, FeO, MgO, CaO, $Na_2O$, $K_2O$, $H_2O$

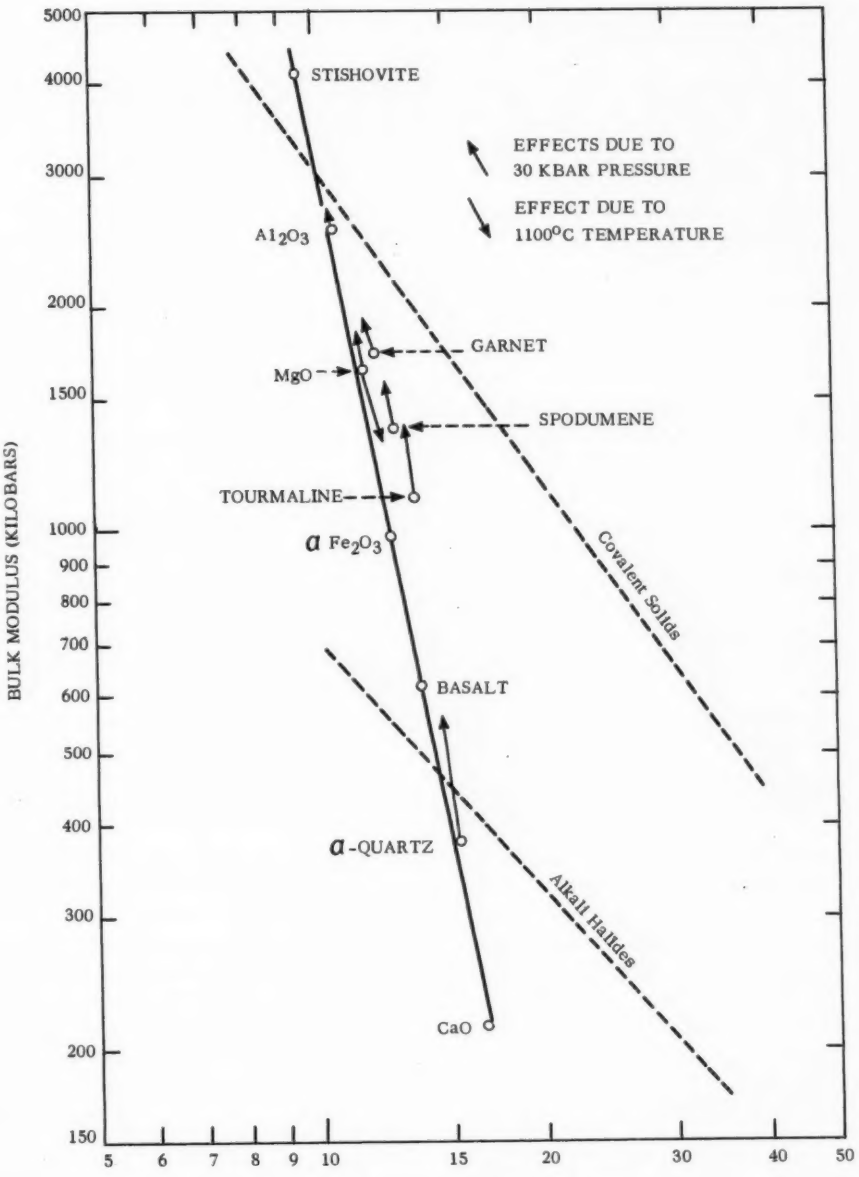



**FIG. 1. VOLUME PER ION PAIR**

These tentative conclusions are based on an analysis of existing published data. When confirmed by experiments on controlled synthesized minerals, it may be possible to duplicate and measure the geophysical conditions found at 50-100 kilometers in the earth. Data from these experiments should prove useful in many scientific disciplines ranging from geochemistry to seismology.

Dr. Orson L. Anderson of the Lamont Geological Observatory is conducting the laboratory experiments and analysis. This work is being performed under AFOSR contract AF 49(638)-1355. ★

# LARGE-VOLUME HIGH-INTENSITY PULSED MAGNETIC FIELDS

MAX SWERDLOW, Directorate of Physical Sciences, AFOSR

Pulsed magnetic fields of 500 kilogauss* have been produced in a large volume at the AFOSR-sponsored National Magnet Laboratory at the Massachusetts Institute of Technology. These fields are produced by beryllium-copper helical coils in a volume 2 cm in diameter and 2 cm long, and with a pulse duration of 0.5 milliseconds (0.0005 seconds). The new coils provide fields with volumes on an order of magnitude greater than those available previously. With this larger volume, many experimental studies of the properties of matter are now feasible in the 500-kilogauss range.

Major advances in continuous magnetic fields have been made at the National Magnet Laboratory with large-volume, water-cooled, high-power solenoids. The present record of continuous magnetic field obtained is 255 kilogauss. (See OAR Research Review, "A New World Record---," Vol. III, No. 9, November 1964). The long times available with continuous fields permit high-resolution and high-sensitivity measurements. But the stringent limitations of available power, cooling, and the strength of materials limit the ultimate field attainable with continuous field techniques. In order to reach higher fields, pulse field methods have also been developed at the National Magnet Laboratory by Simon Foner, Walter Fisher, and D. Bruce Montgomery. The purpose of this research has been twofold: first, to permit extension of high field experiments beyond the region currently feasible with continuous magnetic-field technology; and second, to examine new coil structures and materials which may be useful for the next generation of continuous or pulsed high fields magnets. Both short-pulse-time (less than 1 millisecond) coils and long-pulse-time (10 millisecond) very uniform field coils have been tested to significantly higher fields than heretofore feasible.

The pertinent parameters for pulsed-field coils differ from the continuous field regime in several respects. The maximum pulsed field attainable in a given volume is determined by the available stored energy, subject to the conditions that the pressures and temperatures generated in the coil do not exceed the bursting point or melting temperature, respectively. The present capacitor bank at the National Magnet Laboratory, which has a stored energy of 100 kilojoules*, permits both of these limits to be reached with many of the high field pulsed coils tested recently (Figure 1). Cooling during the pulse is not generally attempted for the highest field coils; thermal inertia prevents melting. The volume normally used for cooling is replaced by conductors for higher efficiency.

The highest reproducible fields have been made with continuous helical coils machined from beryllium-copper alloys. For small coils 750 kilogauss were generated several years ago in volumes of 0.5-cm diameter by 0.5-cm length for a half period of 120 microseconds (0.000120 seconds). The present coils generate 550 kilogauss over volumes of 2-cm diameter by 2-cm length for 0.5 millisecond half periods with 60 kilojoules (Figures 2 and 3).

For many experiments, fields of high uniformity and relatively long pulse times are essential. With a fixed capacity, the easiest method for achieving long pulses is

*One kilogauss equals 1000 gauss. A gauss is a unit of measurement of magnetic field intensity. The natural magnetic field of the earth, which aligns the compass needle, is about one-half gauss.*

*One kilojoule equals 1000 joules. A joule is a unit of energy or work. The work done when a force of one newton produces a displacement of one meter in the direction of force (1 joule = $10^7$ erg = 0.2390 calorie). One kilojoule of energy would be sufficient to raise the temperature of a pound of water about one degree Fahrenheit.*

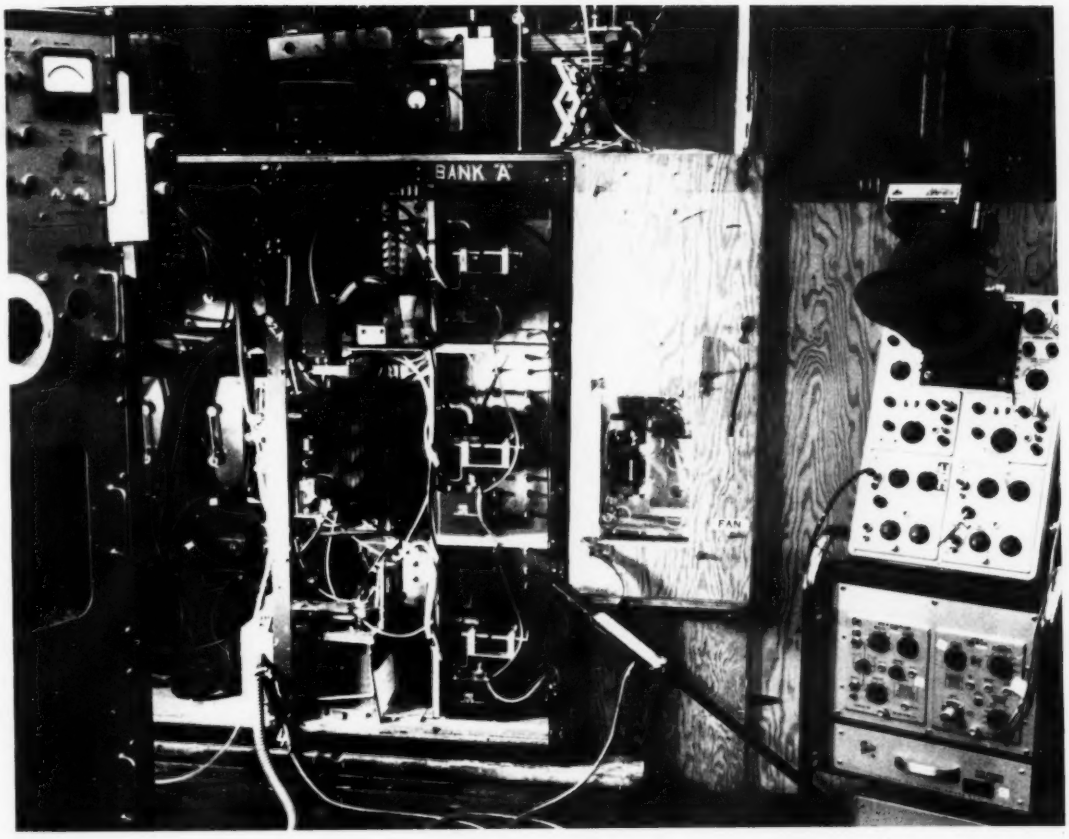



*Fig. 1* *Front Section of 100 kilojoule capacitor bank at the National Magnet Laboratory. The power supply on the left charges the bank to 4 kilovolts. Switching is accomplished by 3 enclosed sparkgaps, located at the center of the photograph (under Bank A) and partly obscured by exposed triggering sparkgaps. Some capacitors and coaxial cable connections to the current bus bar are visible at the left. The pulsed field coil is mounted in a protective enclosure and can be seen through the small window.*

the use of multilayer coils. Such compensated solenoids with square copper insulated wire cooled to liquid nitrogen temperatures have generated 250 kilogauss in a 2.5-cm diameter for 10 milliseconds with 55 kilojoules. Beyond this field, the copper yields. To increase the field capabilities of such coils, beryllium-copper wire coils are currently being tested.

The interaction of the field and current in the magnets produces tremendous forces. At 500 kilogauss, the stress in the winding approaches 150,000 pounds per square inch, which is close to the ultimate yield strength of the beryllium-copper alloys used. Experience with the large coils has shown that they, indeed, begin to yield at this point, whereas the small coil structures (with relatively small field volumes) can, at times, be subjected to somewhat greater fields. The coil structures for large field volumes are also becoming considerably more massive requiring very large flanges and heavy clamping bolts. Present fields in the region of 500 kilogauss, therefore, appear to be approaching the ultimate value expected for the alloys currently available. ★

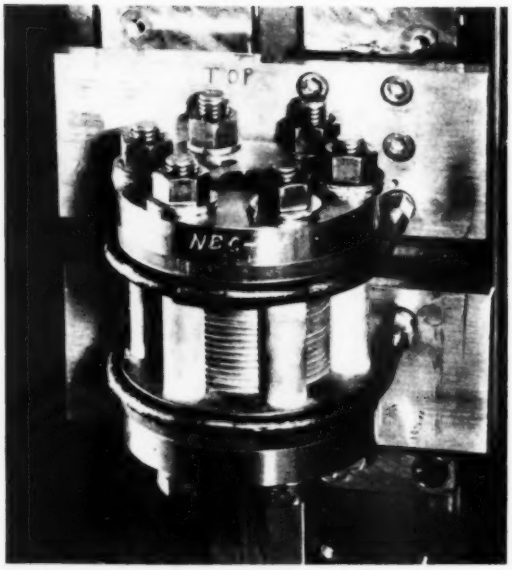



*Fig. 2*
*View of large-volume helical, beryllium-copper, pulsed-field coil mounted on current bus bar by pressure contact applied by U bolts.*

*Fig. 3* *Half section of wire wound, 1 inch I.D., long time constant (10-msec) pulsed-field coil. This coil is made of square insulated copper wire, contained by glass-reinforced plastic outer and inner tubes, by stainless steel interlayer supports, and by epoxy impregnation. It is immersed in liquid nitrogen to reduce resistance. The cross section shows the distortion of the solenoid after failure at fields of over 250 kG. The inner winding layer originally had a central spacer in order to obtain a corrected field, uniform to one part in $10^3$ over a 1-inch diameter sphere. The outer dimensions of the copper solenoid are 3¼ inch diameter by 3½ inch length.*

# DIFFUSION ANALYSIS BY X-RAY EMISSION*

1ST. LT. FRANK E. RIZZO, Metallurgy and Ceramics Research Laboratory, ARL

When two metals are placed in contact at elevated temperatures, a diffusion or intermingling of the atoms is found to occur. In the solid state, the process of diffusion is important in such common operations as soldering and tinning as well as in more exotic operations such as the diffusion bonding of protective coatings on refractory alloys. The amount of diffusion of a particular type of atom is proportional to the concentration gradient of that element, the diffusion tending to eliminate concentration gradients. After a known time at a temperature of interest, the proportionality constant, known as the diffusivity or diffusion coefficient, can be calculated from data of concentration versus distance in the diffusion direction. Chemical analysis, hardness measurements, phase transitions, lattice parameter variation and electron microprobe analysis all have been used to determine the required concentration profiles. In the course of an investigation of the diffusion of electroplated coatings, it became apparent that none of these techniques would be suitable. Consequently, a method of employing X-ray emission was devised.

The physical characteristics of this method can be illustrated by considering a simple experiment. A sample material, after being sufficiently excited, gives off part of its excess energy in the form of X radiation upon returning to its ground state. Part of this radiation, known as the X-ray spectrum, is characteristic of the atom being irradiated. Further, the intensity of this radiation is proportional to the number of these atoms in the irradiated volume of the sample. In many cases, by measuring the intensity of the various wave lengths given off when a sample is irradiated, both the identity and the relative amounts of the various atoms present can be simply determined.

*This paper is based on part of a thesis submitted to the University of Cincinnati by F. Rizzo in partial fulfillment of the requirements for the Ph.D degree.

To apply the X-ray emission method to the determination of concentration profiles, the standard microprobe system of a General Electric XRD-5 X-ray spectrometer was modified to allow an irradiated sample to be moved accurately with a motor-driven micrometer. The effective shape of the irradiating beam of X rays was also modified by masking part of the sample with an aluminum shield fixed to the sample chamber.

In order to obtain the required concentration profiles, nickel metal was electroplated onto copper at various conditions of plating temperature, pH, concentration, and current density. These samples were individually sealed under vacuum in Vycor tubing, and diffusion-annealed at 1000$^{o}$C for 24 hours. The face perpendicular to the diffusion interface was then polished, and the sample was placed in the X-ray spectrometer. The intensities of the most intense wave lengths of the copper and nickel spectra were then measured. Next, the sample was moved by the motor-driven micrometer so that a small area of the sample face was withdrawn from the exciting beam of radiation. The orientation of the sample was such that the length of the area withdrawn was approximately 16 mm in the direction perpendicular to the diffusion direction. It was assumed that the initial uniformity of composition persisted in this direction since net diffusion occurs only in the direction in which there is a gradient. The width of the area withdrawn in the direction of the concentration gradient could be varied from approximately 0.00005 mm upward. The decrease in intensity of the copper and nickel characteristic wave lengths that occurred was attributed to the material withdrawn. The decrease in copper-characteristic wave length was taken to be proportional to the number of copper atoms being irradiated, and the decrease in nickel-characteristic wave length proportional to the number of nickel atoms. The atomic per cent of copper in the area of the sample face

withdrawn was calculated as the number of atoms of copper determined above divided by the sum of copper and nickel atoms. The sample was repeatedly moved until the calculation indicated that the diffusion zone was totally removed from the irradiating beam. Since this method required less time than the usual diffusion analyses, a complete statistical experiment, including separate diffusion samples at all combinations of three plating temperatures and current density, as well as two pHs and concentrations, was possible. The results indicated that the experimental variables, as well as several of their interactions, caused statistically significant variations in the diffusivity. This indicates that the effect of plating conditions cannot be neglected in determining diffusion coefficients.

As well as being applicable to the determination of diffusion coefficients, which are so often required in high-temperature design, the method can be used to study other phenomena involving unidirectional concentration gradients, such as polarization and surface reactions. ★

## SCIENTIFIC *note*

Deep Space Rocket Experiment: On 12 May 1965, AFCRL launched a 4-stage Blue Scout Jr. research rocket in the 5th of a series of scientific deep space probes to learn more about the distribution of energies in the earth's inner radiation belt. The rocket reached an altitude of about 7,400 nautical miles. It was launched from Cape Kennedy and carried a 46.5-pound pay-load package. Objectives of the flight were to obtain a vertical profile of the energy spectrum and pitch angle distribution of trapped charged particles in the earth's radiation belt from about 1,000 miles to a peak altitude of about 7,400 nautical miles. The trajectory carried the pay load through the radiation belt near the magnetic equator. It came down over the Indian Ocean. The vehicle reached apogee 1 hour and 25 minutes after launch. The total flight lasted 2 hours and 54 minutes. (Space Physics Laboratory, AFCRL) ★

# ON THE ROCKS - In the Critical Region

**DR. AMOS G. HORNEY**
Directorate of Chemical Sciences, AFOSR

Everyone who has ordered his refreshment "on the rocks" is familiar with certain aspects of phase transitions. A property of great importance in understanding the details of such processes is the heat capacity of the substance undergoing the transition. The existence of a phase transition may be detected, if all else fails, by demonstration of a discontinuity in the variation of heat capacity with temperature. (Fig. 1)

The methods of statistical mechanics give a good understanding of much of the behavior of matter undergoing phase transitions. These methods are based on rather simple models and assume regular behavior. Complications arise principally when "fluctuation phenomena" become important. In the usual textbook system, low level fluctuations are avoided (or ignored). Professor Hartland H. Schmidt and his associate, Mr. Jack Opdycke, with the aid of an AFOSR Directorate of Chemical Sciences contract, stringently tested current theories. These experimenters at the riverside campus of the University of California purposely sought out systems which would be subject to serious fluctuation effects. This was done in order to provide a more stringent test for current theories of the liquid state. For instance, for each substance there is a region of temperature and pressure called "the critical region" in which the properties of the gaseous and liquid states of the substance become so similar as to approach identity (reaching it at the "critical point"). In this region, prediction of the properties of the substance by theory becomes difficult since fluctuation effects may not be neglected. Data in this region provides an important test of theory. However, it also presents a stringent test for the experimenter since the quantities of interest can depend on minute differences between large quantities which in themselves are difficult to measure with precision.

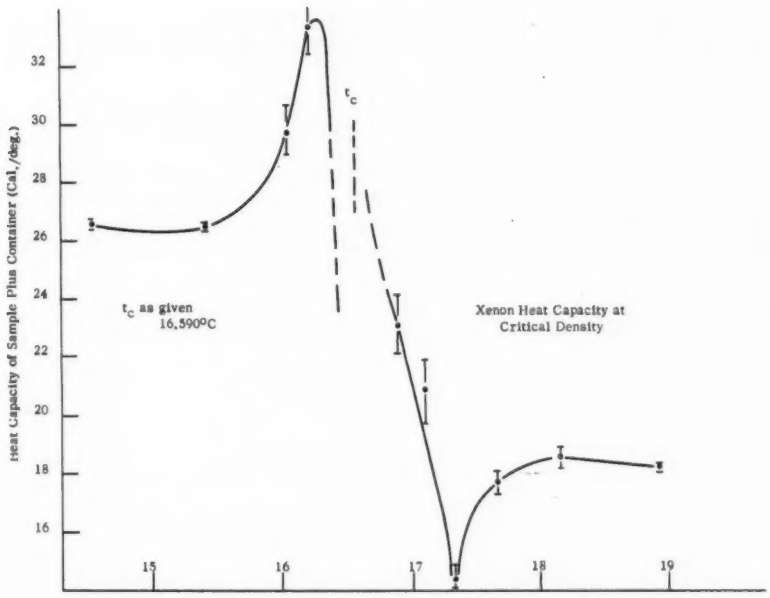



FIG. 1. DEGREES CENTIGRADE

In order to measure the heat capacity of vaporization of liquid xenon, an important but poorly understood transition, the well-known properties of the melting of ice, a better known process, were used. Figure 2 shows the core of the "ice-calorimeter" used, one of the most precise instruments of its class in existence. Difficulties which had rendered previous measurements questionable were avoided by such techniques as stirring the low-temperature liquids to avoid thermal gradients. The results of the measurements have been analyzed by "Cluster Theory" and related to similar measurements on inhomogeneous systems (mixtures). As the name implies, this theory attaches particular importance to local aggregates of molecules which account for the detailed variation of such quantities as heat capacity. Indeed, such a familiar liquid as liquid water at room temperature is thought to be composed of "fleckering clusters" of water molecules. The behavior of systems such as $H_2O$ which, from the statistical mechanical viewpoint, are of horrendous complexity, can only be understood after work on the "simpler" systems such as liquid xenon. ★

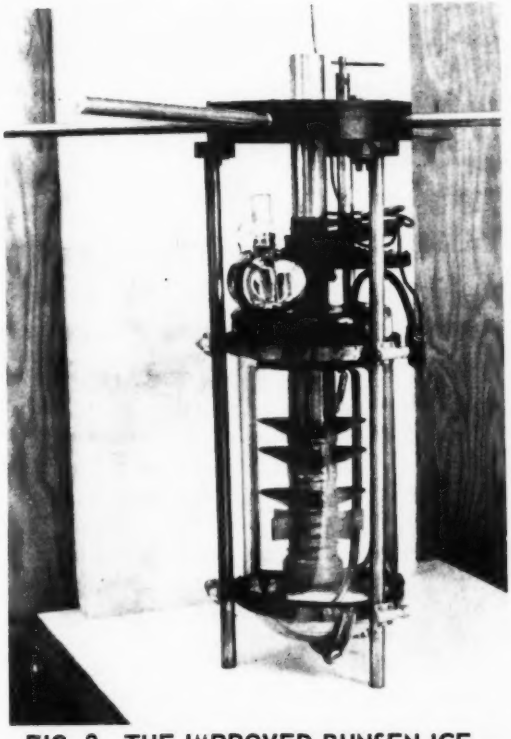
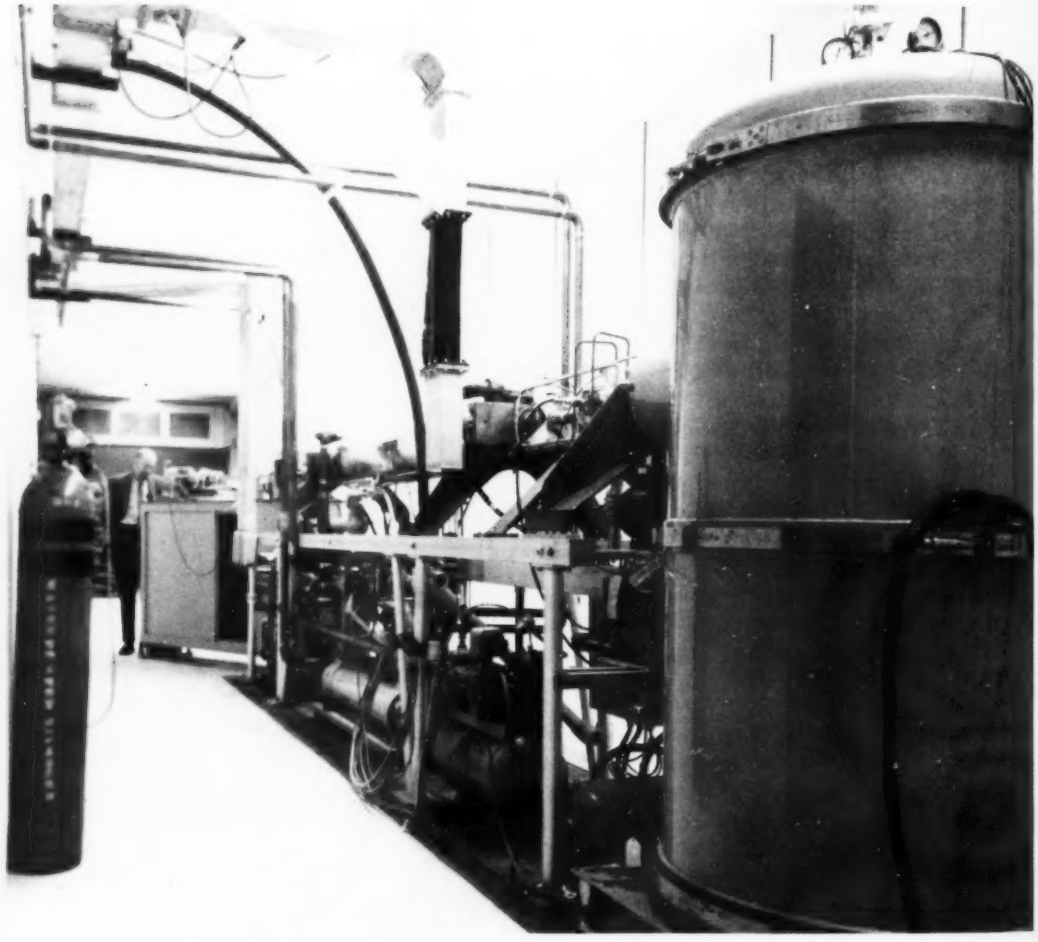


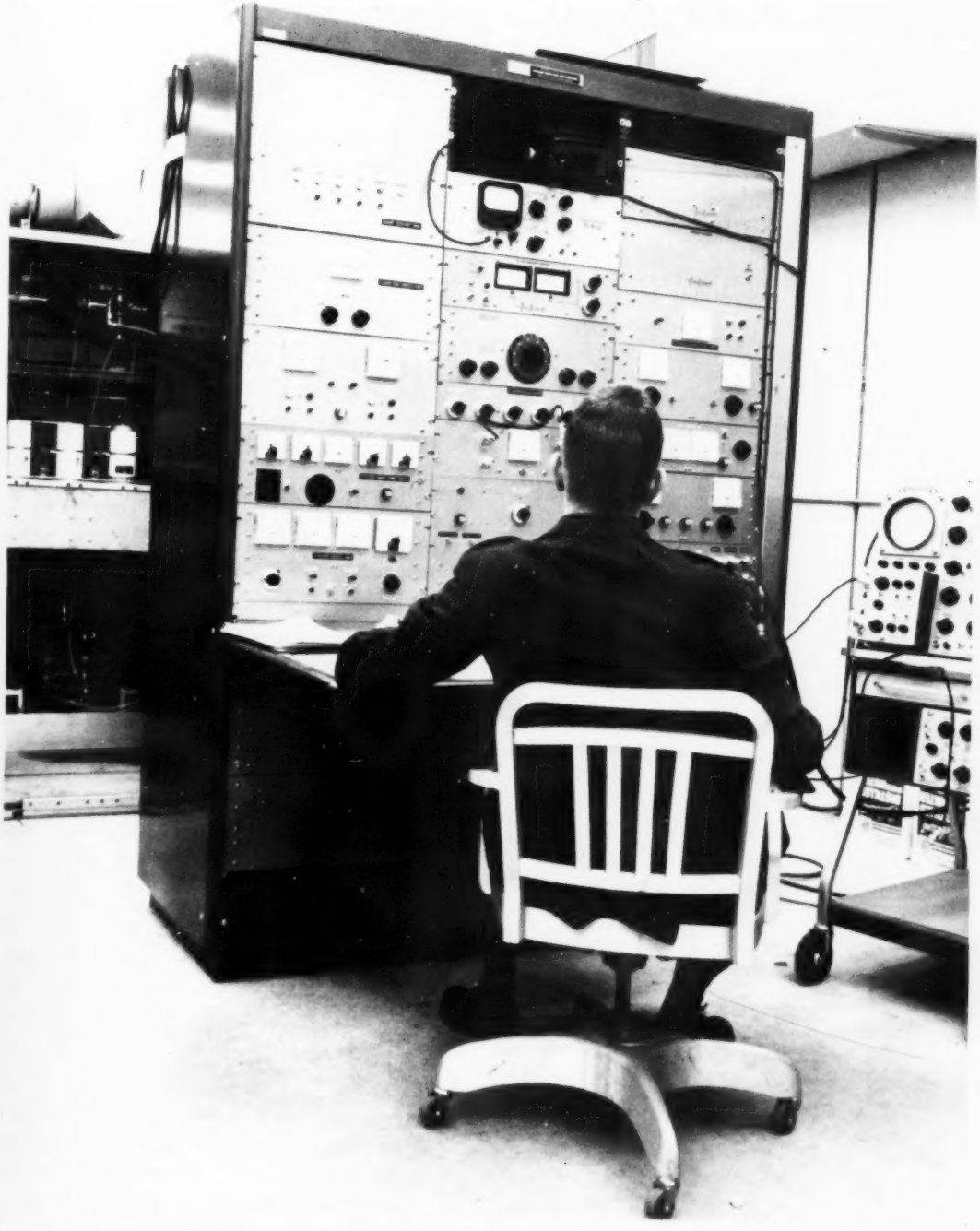
FIG. 2. THE IMPROVED BUNSEN ICE – CALORIMETER WITH SUPPORT RODS

# NEW AFCRL LINEAR ACCELERATOR

*New Linear Accelerator: A new 12-Mev linear accelerator has been placed in operation at AFCRL. The accelerator will be used primarily to study the harmful effects of radiation on electronic materials and devices. These studies will include displacement damage in crystals, transient radiation effects from intense ionizing bursts of radiation, and effects on electron components and devices. In addition to the work carried out by AFCRL scientists, time on the machine will be made available to scientists from other Government agencies, and AFCRL contractors. In initial tests, the accelerator exceeded specifications. Energies as high as 18 Mev have been obtained. The accelerator is one of four major equipments operated by AFCRL for radiation-damage research, the other three being a Van de Graaff generator, a Cobalt-60 source, and a Dynamitron electron accelerator. (Solid State Sciences Laboratory, AFCRL.)*



12 – MEV ELECTRON LINEAR ACCELERATOR AT AFCRL



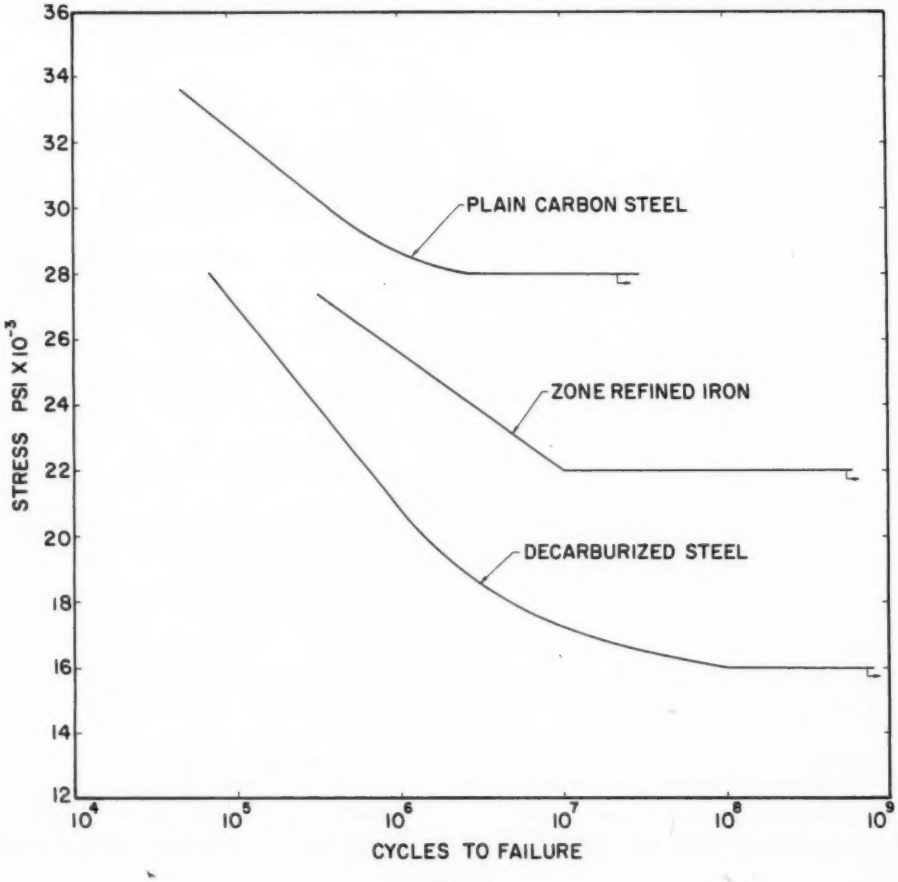
MAIN CONSOLE FOR 12 – MEV ELECTRON LINEAR ACCELERATOR AT AFCRL

# The Fatigue Limit Behavior of Zone Refined Iron

A. M. ADAIR and DR. H. A. LIPSITT, Metallurgy and Ceramics Research Lab, ARL

The failure of parts in service under cyclic or repeated loading continues to constitute the largest percentage of failures encountered by both the civilian and military community. This type of failure--classed as fatigue--has been and continues to be investigated in its fundamental aspects and from an applied engineering approach. The characteristic fatigue limit, i.e., a limiting stress below which failures do not occur, has been studied by many investigators and is a subject of considerable interest to ARL scientists. A complete understanding of the mechanism of this fatigue limit is believed to be an essential factor to consider when developing and selecting materials which will be subjected to dynamic loading.

A few years ago, Lipsitt and Horne (1) hypothesized that the fatigue limit resulted from dynamic strain aging during testing which imparted sufficient strengthening such that damage was overcome at some lower limiting stress and failures no longer occurred. This hypothesis was supported by the results obtained when the fatigue limit knee position, i.e., the number of cycles of testing at which failures no longer occur, was shifted from about 3 x $10^6$ cycles for a plain



carbon steel to $10^8$ cycles for a carefully decarburized steel. Since that time, other investigators have suggested that the fatigue limit of steels stems from a basic property of iron, or that restrictions of grain size and strength level should be placed on the proposed general applicability of the strain aging hypothesis.

A study was undertaken at ARL to determine the fatigue limit characteristics of zone-refined iron--a material slightly superior to the decarburized steel used by Lipsitt and Horne with regard to the strain aging elements carbon and nitrogen. These tests were intended to show whether the attainment of low levels of carbon and nitrogen is of itself a sufficient cause for the observed shift of the fatigue limit knee position to long lives.

The results of this study are shown in the attached figure, along with those for the plain carbon steel and decarburized steel used by Lipsitt and Horne. The fatigue limit knee position is seen to extend to longer lives in the indicated order: plain carbon steel, zone-refined iron, and decarburized steel, respectively. If total carbon and nitrogen content alone dictates the position of the fatigue limit knee, the knee positions for the zone-refined iron and the decarburized steel should have been much nearer to one another. The fact that they differ by one full log cycle is believed to be due to carbon and nitrogen being in solution in the zone-refined iron and thus able to enter into the strain aging process; whereas the carbon and nitrogen in the decarburized steel are present as stable carbides and nitrides and probably very finely dispersed. This opinion is supported by uniaxial tests on the two materials in which their strain aging response was indicated by straining at room temperature, aging one hour at 100° C, and retesting. A substantial yield point returned for the zone-refined iron, indicating that a significant amount of carbon and nitrogen were in solution. On the other hand, the decarburized steel showed no response to the same strain aging treatment.

While these results are considered to support the strain aging hypothesis for the fatigue limit, unequivocal substantiation or rejection must await tests on a ferrous material which can be proven to have no carbon or nitrogen in solution during fatigue testing.

This research was funded by the Air Force In-House Laboratory Independent Research Fund. ★

*REFERENCE*

*(1) Lipsitt, H. A. and G. T. Horne: Proc. ASTM, 1957, Adair & Libsitt, ARL Vol. 57, pp. 587-99.*

# AFCRL ROCKET PROGRAM: *HISTORICAL PERSPECTIVE*

**CAPT. ADELBERT McINTYRE, Technical Plans and Operations, AFCRL**

On 22 August 1946, from the White Sands Proving Grounds, AFCRL launched its first sounding rocket, one of the early V-2's. The V-2 failed. But for AFCRL (and for environmental science itself) the launch was a historic one for it was to shape the character of a large segment of AFCRL's research program; it marked the beginning of rocket probe research at AFCRL that has continued for almost two decades.

Since the first V-2 flight (to measure day airglow, densities and temperatures), AFCRL has launched 518 large sounding rockets. This figure, which does not include an even larger number of smaller meteorological rockets, is the largest number of sounding rockets launched by any group or laboratory in the country, and, by safe inference, in the world. The AFCRL program has given scientists all over the world their most detailed picture of the earth's dynamic environment.

A chronological history of AFCRL's rocket and satellite experiments has been recently assembled. The document, soon to be published as an AFCRL report, lists dates,

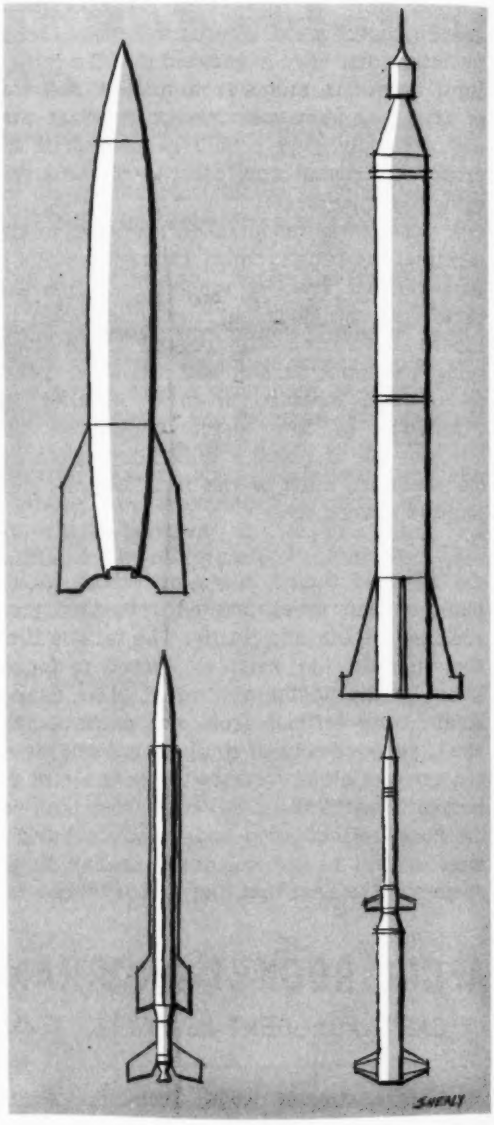
launch sites, vehicle types and the nature of the experiments of all AFCRL rocket and satellite investigations from the beginning of the program through 1964.

In the early days of the V-2's, failures far outnumbered successes. For the scientists who carefully designed and fabricated the pay-load packages, disappointments far outweighed the rare delight of examining data which came, for the first time, from within the actual environment of the upper atmosphere, then an unknown entity.

AFCRL scientists sent experiments aloft on a total of 14 V-2s, the final flight being in August of 1952. But long before that time AFCRL, together with the Naval Research Laboratory, had taken the initiative in developing a successor to the V-2, the Aerobee. The Aerobee, developed under AFCRL contract by Aeroject General, became the workhorse of scientists exploring the upper atmosphere--not only at AFCRL, but in Navy and Army laboratories as well. The first of the Aerobees carrying an AFCRL pay load was launched from Holloman AFB in December of 1949. Of the 82 rockets launched by AFCRL in the years 1950 through 1956, all but 12 were Aerobees.

Beginning in 1955, the various Nike combinations--Nike-Deacons, Nike-Cajuns, Nike-Apaches and so on--offering advantages in cost and altitude attained, were increasingly used. Altogether, more than 20 different rocket types and combinations have been used by AFCRL.

The first US satellite, the 1958 Alpha launched in January 1958, carried an AFCRL experiment--a microphone-type micrometeorite detector. Since then, AFCRL scientists have had one or more experiments aboard a total of 30 Air Force and NASA satellites--some of these entirely devoted to AFCRL experiments. AFCRL satellite experiments were designed to measure such phenomena as cosmic-ray fluxes, micrometeorites, atmospheric attenuation of optical radiation, ion-electron structures and the earth's magnetic field. Under its rocket and satellite program, AFCRL has examined almost every aspect of the earth's upper atmosphere and near-space environment. The largest programs can be grouped under certain broad categories--atmospheric winds, temperatures and densities, the electrical structure of the ionosphere, solar ultraviolet radiation, atmospheric composition, the earth's radiation belts, cosmic-ray activity, airglow and the aurora. Rockets have been launched from sites all over the world--from Sweden to Johnson Island in the Pacific where AFCRL launched 29 rockets in association with the 1962 series of nuclear tests. ★



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